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Environmental Effects of Dredging Technical Notes

Documentation of the RUNQUAL Module for ADDAMS: Comparison of Predicted Runoff Water Quality with Standards

Purpose

This technical note has a twofold purpose: to describe a technique for comparing the predicted quality of surface runoff from confined dredged material disposal areas with applicable water quality standards and to document a computer program called RUNQUAL, written for that purpose as a part of the Automated Dredging and Disposal Alternatives Management System (ADDAMS).

Background

The U.S. Environmental Protection Agency (EPA) (1980) has published guidelines for implementing the 1977 amendments of section 404 of the Clean Water Act for water quality impacts associated with dredged material disposal. Proposed testing requirements define dredged material according to four categories, with Category 3 consisting of material proposed for confined disposal that has "potential contamination of the receiving water column only." The proposed testing requirements call for evaluation of long-term water column impacts of disposal area surface runoff discharge. In addition, under section 401 of the Clean Water Act, a water quality certification is required from the state in which the surface runoff occurs. The certification can include water quality standards for contaminants of concern and should specify the size of a mixing zone for initial dilution in those cases where receiving water quality standards may be exceeded.

In this context, surface runoff refers to the discharge from the surface of dewatered dredged material in response to a precipitation event. The quality of surface runoff from confined dredged material disposal areas during both the wet anaerobic and the dry oxidized stages is a major environmental concern

associated with such disposal. Comparison of water quality from surface runoff with water quality standards is analogous to the comparisons for effluent discharges. Techniques for predicting effluent quality are presented in *Environmental Effects of Dredging Technical Notes* EEDP-04-1 through EEDP-04-4 (Palermo 1985) and EEDP-06-13 (Palermo and Schroeder 1991). Guidance for performing a surface runoff quality test is provided by Lee and others (1991). After such tests are performed, each contaminant of concern is compared with applicable water quality standards. Prediction of surface runoff quality is covered in *Technical Note* EEDP-02-3 (Skogerboe and Lee 1987), which addresses analysis of surface runoff from confined upland disposal sites to develop appropriate management plans before dredging. This procedure was developed as part of the Field Verification Program.

After predicting surface runoff water quality, and comparing this with standards and computing the dilution requirements, as described in this technical note, the required size of a mixing zone is computed. Guidance for calculating the size of the mixing zones can be found in *Technical Note* EEDP-04-5 (MacIntyre 1987). The required dilution of each contaminant of concern to meet its respective water quality standard must be determined prior to calculating the size of the mixing zone.

Additional Information

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RUNQUAL Application of ADDAMS

Requirements

Surface runoff is the drainage of water by overland flow resulting from a precipitation event. The runoff often contains quantities of soil nutrients and contaminants scoured from the surface of the land. Predictions of soil loss and surface water quality are developed by simulating the runoff process in a laboratory test.

The surface runoff water quality test was developed under the Environmental Impact Research Program to predict soil loss and surface water quality at U.S. Army Corps of Engineers construction sites (Lee and Skogerboe 1984). The test was further refined and field verified for confined upland disposal of contaminated dredged material under the Field Verification Program (Skogerboe and others 1987). The test apparatuses consist of the U.S. Army Engineer Waterways Experiment Station's (WES) rotating rainfall disk simulator, which is

designed to duplicate the kinetic energy of natural rainfall (Westerdahl and Skogerboe 1982), and large laboratory lysimeters (25 by 5 by 2 ft) placed in a temperature-controlled greenhouse.

Sediment is collected from a proposed dredging site, brought to WES, and tested during both the wet anaerobic and dry oxidized stages. The wet anaerobic stage represents dredged material immediately following drainage of the ponded water from the confined disposal facility. Its oxidation state is the same as that of the original sediment. The dry oxidized state represents aged dredged material following crust formation of the surface material. Results are then statistically compared to water quality criteria chosen by the agency sponsoring the study (Skogerboe and Lee 1987). Predicted concentrations can be used with appropriate water quality standards to determine the size of the mixing zone required to dilute the runoff discharge to an acceptable level. Before mixing zone calculations are made, the required dilution of each contaminant of concern to meet water quality standards must be calculated.

Comparison of the predicted surface runoff concentration with the water quality standard and, if necessary, calculation of the dilution required to meet the water quality standards must be determined for each contaminant of concern. For some projects, the number of contaminants of concern can approach a hundred. The predicted surface runoff concentration during each of the two stages, the water quality standard, and the background concentration of the contaminant in the receiving water all influence the dilution required. Further complicating the process is the fact that any of these concentrations may exceed the others, and some of the concentrations may be below the detection limit of the chemical analysis used to predict the surface runoff concentration. Because the computational effort and data management effort required for such an evaluation can be substantial, a computer program has been developed to efficiently perform the required calculations, manage the data, and present the data and comparisons in a manner that can be easily interpreted.

RUNQUAL Capabilities

The RUNQUAL module, a computer program for surface runoff quality described in this note, has been developed as part of the Automated Dredging and Disposal Alternatives Management System (ADDAMS) and can be run on a personal computer. ADDAMS is an interactive computer-based design and analysis system in the field of dredged material management. The general goal of the ADDAMS is to provide state-of-the-art computer-based tools that will increase the accuracy, reliability, and cost-effectiveness of dredged material management activities in a timely manner. ADDAMS is described in more detail in *Technical Note* EEDP-06-12 (Schroeder and Palermo 1995).

RUNQUAL has the following capabilities:

- Computes predicted dissolved and total contaminant concentrations in the surface runoff discharged from a confined disposal site using surface runoff quality test data.
- Compares predicted surface runoff concentrations with specified water quality standards.
- Computes required dilutions of surface runoff discharge to meet specified water quality standards, considering background concentrations in the receiving water.

Availability

RUNQUAL, as well as other modules of ADDAMS, is available through the Information Technology Laboratory of the U.S. Army Engineer Waterways Experiment Station. See Appendix A for an order form.

Using the RUNQUAL Module

The RUNQUAL module employs a menu-driven environment with a full-screen data entry method. The initial menu contains options for entering/editing input data, selecting existing data files or performing file management operations, selecting/entering/editing water quality criteria or standards, performing calculations, printing output, and exiting the RUNQUAL module. In general, single keystrokes are required to select menu options displayed on the screen. Cursor keys are used to select between highlighted input fields much like a spreadsheet program. Results from computations are generally displayed in tabular format on the screen; these can then saved in ASCII files or sent to a printer, or both. General on-line assistance is available by pressing the F1 key. The F2 key offers detailed assistance on the highlighted input field.

Input/Output

The main data requirements for the RUNQUAL module include surface runoff quality test conditions for both the wet anaerobic and the dry oxidized material and results, background receiving water concentrations, and water quality standards for contaminants of concern. Other data describing the samples and parameters used in the surface runoff quality tests can also be entered for documentation purposes. The input data are stored in a file with a user-specified name and an extension of .RUI. The water quality standards are stored in a file called CRITFILE.DAT, the same file as used with the EFQUAL module.

The final output of the module consists of tabular summaries of surface runoff quality data, predicted surface runoff quality concentrations and water quality standards; absolute and statistical comparisons of predicted surface runoff water quality with standards; and computed dilutions required to meet the standards. The summary of input values and predicted concentrations are stored in a file with the user-specified name with an extension of .RUS, while the results of comparisons and dilution computations are stored with the same

user-specified name but with an extension of .RUC. Table 1 shows the necessary input parameters with their corresponding units. Instructions for data entry and additional descriptive information for some parameters are provided directly on the RUNQUAL input screens or are available from the on-line user guide.

Table 1
RUNQUAL Input Parameters

Parameter	Unit
For each evaluation:	
Descriptive title	N/A
Number of surface runoff replicates	number
For each runoff replicate:	
Sediment age (optional)	years
Rainfall duration (optional)	hr
Rainfall intensity (optional)	cm/hr
Total suspended solids (TSS) concentration	mg/L
For each contaminant of concern:	
Detection limit	µg/L
Test sediment concentration (optional)	mg/kg
Test water concentration (optional)	µg/L
Background water concentration	µg/L
Water quality standard	µg/L
For each contaminant of concern and each surface runoff replicate:	
Surface runoff dissolved concentration	µg/L
Surface runoff total concentration (required only if total concentrations used for prediction of quality or comparison to standards)	µg/L
For each evaluation:	
Estimated surface runoff discharge TSS concentration (required if total concentrations used for prediction of quality or comparison to standards)	mg/L
Percentage increment above background for dilution calculations (used when standards are below or very close to background concentration)	percent

Considerations in Comparing Predictions with Criteria

Contaminants of Concern and Water Quality Standards

Prior to entering water quality standards or surface runoff test data, the user must build a list of all contaminants of concern. This list must contain the names of all contaminants measured in the surface runoff tests or listed in any water quality criteria set of interest, such as the Federal freshwater acute and marine toxicity water quality criteria sets, the Federal drinking water standards, or state water quality standards. The RUNQUAL module comes with a list of contaminants for the Federal freshwater and marine acute toxicity water quality criteria sets. To update the list, the user should select the water quality criteria set option of the RUNQUAL module and then choose the criteria set of interest or build a new criteria set (up to a maximum of 12 sets). The program will display the current list of contaminants and provide instructions for adding or deleting names from the list.

When building or editing the list of contaminants, the user should also enter the available water quality standard for all contaminants of interest. Entry of the standard is made on the same screen in a column adjacent to the entry of the contaminant name. Many of the contaminants initially listed on the screen may not have standards for the selected criteria set but may have values in other criteria sets. A standard entered as equal to or less than zero will be treated as a missing value. Contaminants having missing values in the selected set should not be deleted from the list because the contaminant may be used for other criteria sets.

RUNQUAL allows the user to compare contaminant values with several sets of criteria. The EPA acute water quality criteria for protection of freshwater or saltwater aquatic life are initially available as choices. Chronic criteria are technically inappropriate because water column effects are considered short term because of the intermittent, short-term nature of runoff. As noted earlier, RUNQUAL allows the user to build additional sets of water quality standards (for example, state standards specified under section 401 water quality certifications), which can then be permanently stored in the table of standards for use in future evaluations. The water quality standards may be left blank if a standard does not exist for a particular contaminant. If no water quality standard for a given contaminant is specified in the set of standards selected for comparison, RUNQUAL displays N/A (not applicable) blanks for the standard and comparison results.

Surface Runoff Test Description

Surface runoff test results and related information comprise the majority of the data set that must be entered. For each new data set, a text description of the samples used for the tests can be included for documentation purposes. The description should indicate the oxidation stage of the sediment because

one data set should be entered for the wet anaerobic stage and another for the dry oxidized stage.

The surface runoff procedure requires that the test be performed with a minimum of three replicates. Up to nine replicates can be entered in RUNQUAL. Separate sets of replicates of the surface runoff test may be analyzed for classes of contaminants (for example, metals or organics). Therefore, the definition of a replicate for purposes of RUNQUAL is any separate sample analyzed for chemical concentrations and for which a separate total suspended solids determination is made. The TSS concentrations can be used to differentiate between replicates during data entry. The sediment age, the rainfall duration, the rainfall intensity, and the TSS concentrations for each replicate are then specified. The sediment age is an indication of whether the samples are tested in the wet anaerobic stage or the dry oxidized stage.

Sample Contaminant Data

RUNQUAL displays a table of the contaminants of concern for purposes of entering the surface runoff and other data for specific contaminants. The test data can be entered for any contaminant listed on the displayed table of contaminants by a menu selection. RUNQUAL marks those contaminants with an asterisk on the displayed table for which data have been entered. All data previously entered for a contaminant can be deleted by highlighting the contaminant of interest and then depressing the DEL key.

Once a specific contaminant has been selected for data entry, RUNQUAL presents an input screen for that contaminant. Data from the surface runoff quality test procedure include dissolved concentrations of contaminants, total concentrations of contaminants, and the TSS concentration (see *Technical Note* EEDP-02-3, Skogerboe and Lee 1987). These data are used to compute the contaminant fraction of the TSS and to predict the total concentration of contaminants in the surface runoff for any TSS loading (Skogerboe and Lee 1987). The RUNQUAL module automatically performs the needed data reduction and displays the results.

The test sediment concentration and test water concentration for the contaminant may be entered for documentation purposes; however, these parameters are not used in any calculations. The detection limit, the background water concentration, and the dissolved and total surface runoff concentrations for the contaminant are required for the computations. RUNQUAL displays the TSS concentration for all replicates to aid in replicate identification for each contaminant of concern. Care should be exercised in entering the data to ensure accurate computation of total contaminant concentrations.

Once the dissolved and total concentrations for a replicate are entered, RUNQUAL calculates and displays a value for the contaminant fraction of the TSS. If the contaminant concentration for a replicate as determined by the test is below detection, a zero may be used for ease of data entry; however, the value of the detection limit with a less than sign (<) is displayed by the

program. If the entered value of the dissolved concentration for any replicate exceeds that for the total concentration (a possibility considering variability and low concentrations), a value of zero is displayed for that contaminant fraction. After any replicate data are entered or edited, the program calculates and displays values of the mean and standard deviation for the dissolved and contaminant fractions data. No statistics are displayed for the surface runoff total concentrations; their mean has little value because the suspended solids concentration may vary among the replicates.

Detection Limits

The detection limit entered for each contaminant of concern plays a potentially important role in later computation of dilutions. The value entered should be the detection limit for chemical analysis of the surface runoff samples. If the surface runoff concentration of all replicates analyzed is below detection, the mean is assumed to be zero, and zero is used in subsequent computations. If one or more of the replicates is above detection limit, the detection limit is assumed for any replicates with values below detection in computing the mean. This approach is conservative in that the predicted surface runoff discharge concentration will be higher than if zero were assumed for replicates below detection.

Background Concentrations

The value of background concentration for each contaminant is used for later computation of dilutions. This value must be determined by a separate chemical analysis of the receiving water. If the background water or test water concentrations are below detection, a value equal to the detection limit is used in the computations of required dilution. This assumption is conservative in that the required dilution will be greater than if zero were assumed for the background concentration.

Predicted Surface Runoff Concentrations

The RUNQUAL module computes both predicted dissolved and total surface runoff concentrations. The predicted dissolved concentrations are equal to the mean of the surface runoff dissolved concentrations. If the total surface runoff concentrations will be used in the evaluation, a value of the anticipated runoff TSS concentration must be given to compute the total concentrations. Results from the surface runoff test should be used to determine the surface runoff discharge TSS concentration (see Skogerboe and Lee 1987 and Lee and others 1991). The total contaminant concentrations are computed using the dissolved surface runoff test concentrations, the computed contaminant fractions in the TSS, and the specified surface runoff TSS concentration (Skogerboe and Lee 1987). Either the dissolved or total surface runoff discharge concentrations can be used for comparison with specified water quality standards and for computing required dilutions to meet standards, although typically only the dissolved contaminants readily contribute to toxicity and bioaccumulation.

Evaluation of Results

Comparison of Surface Runoff with Standards

The most useful output from the RUNQUAL module is the comparison of predicted surface runoff concentrations with specified water quality standards. The user has an option to choose either the dissolved or total surface runoff discharge concentrations and one of several sets of standards for the comparison. Any water quality standards imposed as part of a section 401 water quality certification should be based on potential for environmental impact. The standards are usually set in terms of dissolved concentrations, but could be set in terms of total concentrations. Care should be exercised in selecting the appropriate predicted surface runoff concentration (dissolved or total) for comparison to the standards. For example, if the standards are equivalent to or are based on the EPA acute water quality criteria, comparison of dissolved surface runoff concentrations is technically appropriate. The EPA criteria were developed using effects data for exposure of organisms to dissolved concentrations of contaminants.

Whenever a comparison of the predicted surface runoff concentration and a standard is possible and data for multiple replicates are available, a statistical comparison is also made between the mean of the replicate data and the standard considering the variance of the replicate data. The statistical test performed is a two-tailed Student's t-test (Miller and Freund 1985). The result of the test is the confidence level of the result (percent) that the predicted concentration exceeds the standard (i.e., $P > S$) or that the standard exceeds the predicted concentration (i.e., $S > P$). If the confidence is less than 50 percent, the test results indicate that the two values are essentially equal; more specifically, the confidence level of the two values not being equal is less than 50 percent (that is, $P \neq S < 50$ percent).

Calculation of Dilution Factor

If the predicted surface runoff concentration exceeds the standard and the standard exceeds the background concentration, a value for dilution to meet the standard is calculated. However, if both the surface runoff and background concentrations exceed the standard, neither the standard nor the background concentration can be met by dilution. For this case, the user specifies a percentage above the background concentration for which a dilution will be calculated (110 percent of the background or 10 percent above background is recommended for this value). Similarly, if the background concentration is less than but very close to the standard, very large dilution would be required for surface runoff to meet the standard. Consequently, dilution to the percentage above the background is also computed for this condition. If the background concentration is below detection, the detection limit is used for the background concentration. Use of the detection limit for background under this condition is conservative and will result in the largest dilution that could be required for the given standard and surface runoff discharge concentration.

The RUNQUAL module computes dilution factors for each contaminant of concern using the following equation whenever the surface runoff concentration is greater than the standard to be met:

$$D = \frac{P - S}{S - B} \tag{1}$$

where

D = dilution factor required to dilute the contaminant of concern to the appropriate water quality standard, in volume of background water/volume of surface runoff

P = concentration of the contaminant of concern in the surface runoff, μg/L

S = receiving water quality standard for the contaminant of concern, μg/L (or a concentration equal to the specified percentage above background concentration)

B = background concentration of the contaminant of concern in the receiving water, μg/L

Three concentration variables are used in the above equation. When the detection limit and a specified percentage above background are considered, a total of five concentrations are possibly used in the comparison. A total of 60 different conditions are possible, considering every possible combination of the relative magnitude of the five concentrations. However, many of the conditions result in the same conclusion with respect to the interpretation of the comparison and dilution factor required, leaving only eight meaningful cases. These eight cases are illustrated in Figure 1. Additional discussion of each of the eight cases is given below. In addition to the abbreviations *D*, *P*, *S*, and *B* defined above, the following abbreviations are used in the descriptions of the cases:

xB = concentration equal to a multiple, x, of the background and replaces S in Equation 1 when $S \leq xB$

L = detection limit for tests and replaces B in Equation 1 when $L > B$

Case 1: S > L > P. The predicted concentration is less than the detection limit, and the detection limit is less than the standard. The standard is met with no dilution, and the RUNQUAL program displays the comment **D = 0** for the dilution required.

Case 2: L > (S,P). The predicted concentration and standard are both less than the detection limit. The test results do not clearly indicate that the standard is met because the exact concentration of the surface runoff is unknown, and the RUNQUAL program displays the comment **D = 0, L > (S,P)** for the dilution required.

Case 3: (S,B) > P > L. All concentrations are greater than the detection limit, and the predicted concentration is less than the standard and the background. Under these conditions the surface runoff is cleaner than the background receiving water

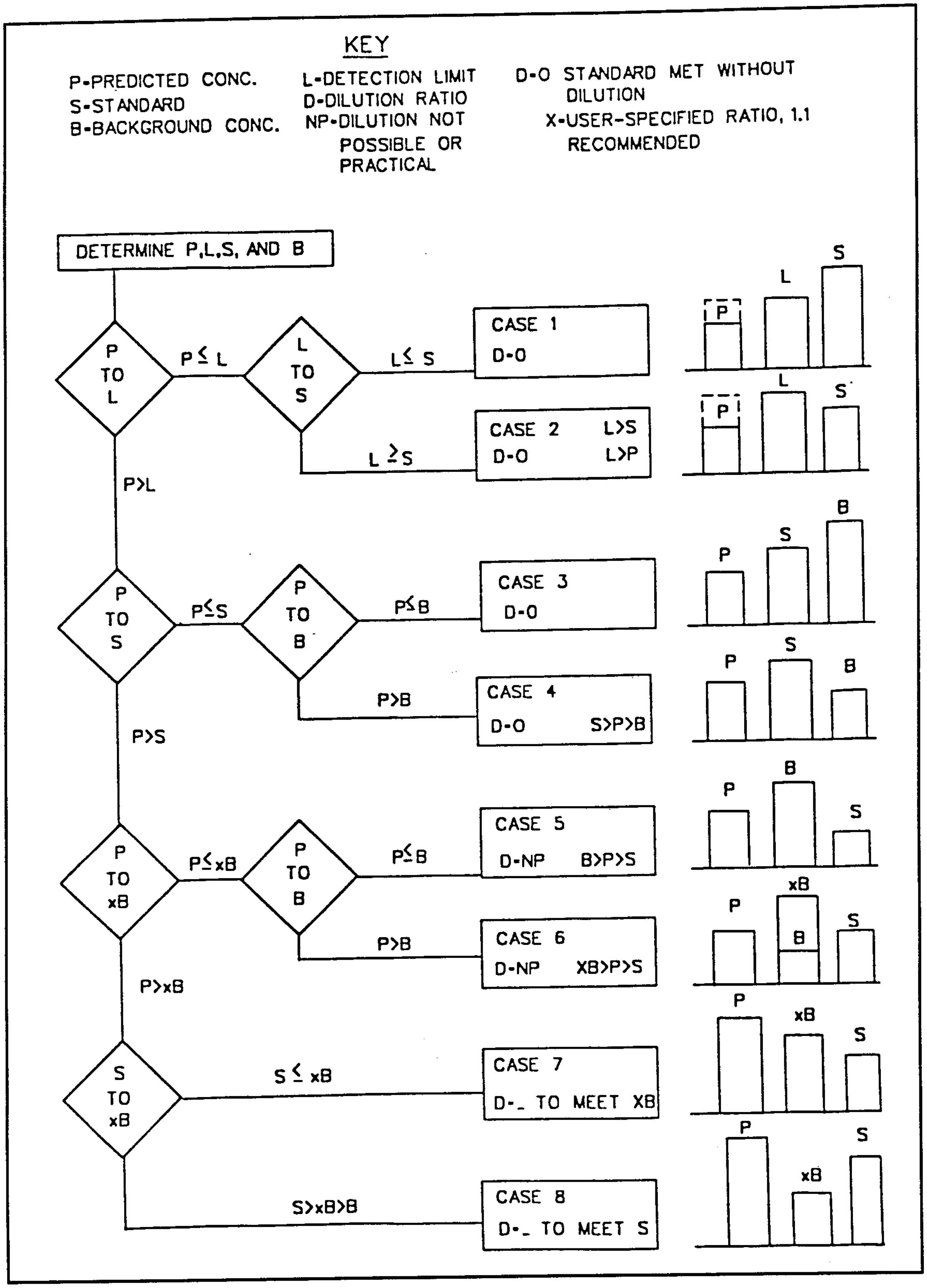

Figure 1. Possible conditions for comparison of runoff concentrations with sediments

for the contaminant of concern. The standard is met with no dilution, and the RUNQUAL program displays the comment **D = 0** for the dilution required.

Case 4: S > P > (B,L). The predicted concentration and standard are greater than the detection limit, and the predicted concentration is less than the standard; however, the predicted concentration is greater than the background. The standard is met with no dilution, and the RUNQUAL program displays the comment **D = 0 S > P > B** for the dilution required. An acceptable deterioration of the background receiving water occurred.

Case 5: B > P > (S,L). The predicted concentration and background are greater than the detection limit and the standard, but the predicted concentration is less than background. Under these conditions the standard is less than the background, and the receiving water is already in violation of the standard. Because the predicted concentration is less than the background, the receiving water will be improved for the contaminant of concern. No dilution is possible, and the RUNQUAL program displays the comment **D = NP B > P > S** for dilution required.

Case 6: xB > P > (B,S,L). The predicted concentration exceeds the detection limit, the standard, and the background; however, the predicted concentration is less than the specified percentage above background. Under these conditions, the predicted concentration is only slightly above the background; therefore, dilution is not practical. In addition, the receiving water is already or nearly in violation of the standard. Because the predicted concentration exceeds the background, some degradation of the receiving water will occur. No dilution is practical, and the RUNQUAL program displays the comment **D = NP xB > P > S,B** for dilution required. If $B < L$, L is used in place of B to compute xB.

Case 7: P > xB > (S,L). The predicted concentration exceeds the detection limit, the standard, and the specified percentage above background, and the specified percentage above background exceeds the standard. Under these conditions, the receiving water is already or nearly in violation of the standard. Since the predicted concentration also exceeds the background, degradation of the receiving water will occur. Dilution to meet the specified percentage above background is calculated because the background exceeds or is very close to the standard. The RUNQUAL program displays the comment **D = ##### to meet xB**, where ##### is the value of the required dilution computed by the program. If $B \leq L$, L is used in place of B to compute xB, xB is used as S, and L is used as B in Equation 1.

Case 8: P > S > (xB,L). The predicted concentration exceeds the detection limit, the standard, and the specified percentage above background, and the standard exceeds both the background and the specified percentage above background. The dilution to meet the specified standard is calculated, and RUNQUAL enters the comment **D = ##### to meet S**, where ##### is the value of the required dilution computed by the program. If $B < L$, L is used in place of B in Equation 1.

Summary

These procedures provide a consistent, rational, and conservative approach to compare predicted surface runoff water quality with water quality standards. In addition, the approach computes dilution requirements that are needed to evaluate mixing zones.

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Appendix A: Request Form for ADDAMS

Please send the ADDAMS diskettes to:

Name and Title ______________________________
Mailing Address ______________________________
and Office Symbol ______________________________
____
Telephone Number ______________________________
Anticipated Uses of ADDAMS ______________________________
____

Requests for ADDAMS must be sent with *formatted* floppy disks. Please circle the applications desired and the number and type of diskettes enclosed.

Requested Modules	Number of diskettes enclosed (all DS)			
	5.25 in. 360 kb	5.25 in. 1.2 Mb	3.5 in. 720 kb	3.5 in. 1.44 Mb
ADDAMS (all modules)	26	14	16	9
ADDAMS DEMO	6	3	3	2
SETTLE	2	1	1	1
DYECON	2	1	1	1
PCDDF	2	1	1	1
D2M2	1	1	1	1
STFATE	10	4	6	3
EFQUAL	1	1	1	1
RUNQUAL	1	1	1	1
EXECUTIVE SHELL	1	1	1	1

Signed______________________________ Date______________________________

MAIL THE COMPLETED REQUEST FORM AND FORMATTED DISKETTES TO:

U.S. Army Engineer Waterways Experiment Station
ATTN: CEWES-IM-DS (Naylor)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199